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# The nature of human adaptation to cold

## Abstract

Human adaptation to repeated short term exposure to cold appears to be characterised by a decreased shivering threshold and unchanged sweating threshold, producing a widening of the inter-threshold zone (1). As a consequence, deep body temperature may fall more rapidly in cold habituated individuals on exposure to cold. This 'hypothermic adaptation' (2) may contribute to a range of problems, from hypothermia in the elderly to insidious hypothermia in occupational groups such as divers.

Although a reduction in the metabolic response to cold is probably the most widely and frequently reported alteration with cold habituation in humans (3), the nature of this attenuation remains unclear. It may be caused by a change in either the threshold for the onset of shivering, or in the sensitivity (gain) of the shivering response, or both. Furthermore, it may be specific to the body temperatures encountered during the habituation regime, or more generalised.

## Disciplines

Arts and Humanities | Life Sciences | Medicine and Health Sciences | Social and Behavioral Sciences

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# THE NATURE OF HUMAN ADAPTATION TO COLD

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## INTRODUCTION

Human adaptation to repeated short term exposure to cold appears to be characterised by a decreased shivering threshold and unchanged sweating threshold, producing a widening of the inter-threshold zone (1). As a consequence, deep body temperature may fall more rapidly in cold habituated individuals on exposure to cold. This 'hypothermic adaptation' (2) may contribute to a range of problems, from hypothermia in the elderly to insidious hypothermia in occupational groups such as divers.

Although a reduction in the metabolic response to cold is probably the most widely and frequently reported alteration with cold habituation in humans (3), the nature of this attenuation remains unclear. It may be caused by a change in either the threshold for the onset of shivering, or in the sensitivity (gain) of the shivering response, or both. Furthermore, it may be specific to the body temperatures encountered during the habituation regime, or more generalised.

It has been reported that the habituation of the initial responses to cold immersion, evoked by repeated rapid falls in skin temperature, is not restricted to the habituating temperature (4) and is due to an alteration central to the peripheral cold receptors (5). With regard to the shivering response, the available evidence is, in part, contradictory. In humans, it has been reported that there is a decrease in the threshold for shivering with habituation but *no change* in the sensitivity of the response (3, 6). In contrast, intrahypothalamic injection of an adrenergic alpha blocking agent (phentolamine) decreases the threshold *and* sensitivity of the shivering response of warm-adapted guinea pigs. This procedure produces responses similar to those normally seen in cold-adapted animals (7).

The present investigation tested the hypothesis that human adaptation to cold immersion is not specific to the body temperatures experienced during the habituation regime (*Hypothesis 1*), and is characterised by a downward shift in the threshold but not the sensitivity of the shivering response (*Hypothesis 2*).

## METHODS

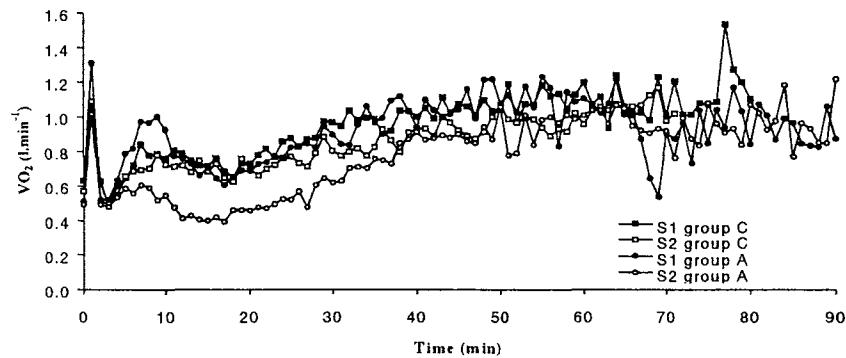
The experimental protocol received approval from the Local Ethics Committee. Fourteen healthy male volunteer subjects aged between 18 and 40 years were recruited for the study. Subjects had no history of cold exposure, or cold-induced illness. Written informed consent was obtained from each subject prior to the trial. The subjects were divided equally and randomly assigned into either an adaptation (A) or control group (C). Both groups undertook two standard head-out immersions (S1 and S2), one week apart, in stirred water at 12°C until either rectal temperature ( $T_{re}$ ) fell by 2°C or 90 minutes had elapsed. In the intervening period, group A undertook 5 immersions in 12°C water, during which their  $T_{re}$  was reduced by an average of 1.16°C, whilst Group C avoided all cold exposure. S1 and S2 were conducted at the same time of day to reduce circadian effects. The experiment began with a 10-minute pre-immersion period in air at thermoneutral temperature for measurement of baseline data.

Oxygen consumption ( $\dot{V}O_2$ ) and  $T_{re}$  were measured every minute. Thermal sensation (1 = unbearably cold, 7 = neutral) and thermal comfort (1 = comfortable, 6 = unbearably uncomfortable) were obtained at 5 minute intervals. Skin temperature was assumed to equate to the temperature of the stirred water. A Wilcoxon test was used to identify any differences in the responses obtained during S1 and S2, over the first 1.16°C fall in  $T_{re}$  (Period 1) and during the remainder of the immersion (Period 2).

## RESULTS

The mean (SD)  $T_{re}$  at the end of S1 and S2 were 35.25°C (0.26) and 35.28°C (0.31) in the C group and 35.26°C (0.37) and 35.37°C (0.36) in the A group. The mean time taken for the  $T_{re}$  to fall by 1.16°C (i.e., duration of Period 1) in S1 and S2 was 36.1 (10.7) and 37.0 (11.1) minutes in Group C and 41.9 (13.9) and 43.9 (15.6) minutes in Group A respectively. There was no difference between the rates of cooling observed in S1 and S2 for either group.

The  $\text{VO}_2$  results are presented against time in figure 1 and for Periods 1 & 2 in table 1.

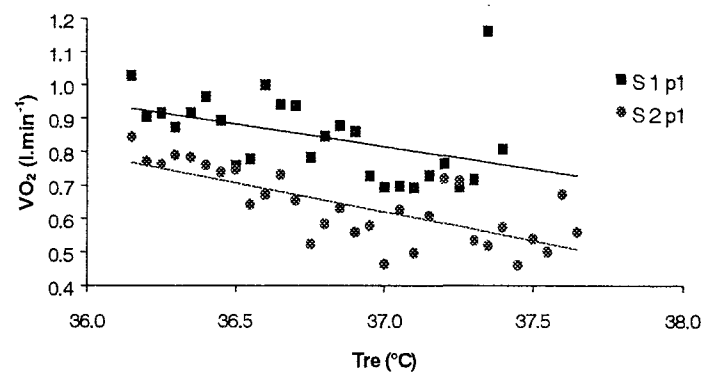


**Figure 1** Mean Oxygen Consumption during S1 and S2 immersions for C and A group (n=14).

**Table 1** Mean  $\text{VO}_2$  ( $\text{L}\cdot\text{min}^{-1}$ ) for both groups during Period 1 & 2 of immersion S1 & S2 (\*  $P<0.05$ )

Group A				Group C			
S1	S2	S1	S2	S1	S2	S1	S2
Period 1	Period 1	Period 2	Period 2	Period 1	Period 1	Period 2	Period 2
0.82	0.6*	1.07	0.96*	0.79	0.72 nsd	1.16	1.03*
% Change -27 %		% Change -10 %		% Change -9 %		% Change -11 %	

Compared to S1, the  $\text{VO}_2$  response in S2 was significantly reduced in Period 1 ( $P<0.05$ ) for Group A but not Group C. In Period 2, both groups demonstrated a significant ( $P<0.05$ ) reduction in the metabolic response.



**Figure 2** Mean  $\text{VO}_2$  of Group A against  $T_{re}$  during Period 1 before and after habituation (S1 v S2, n=7).

No differences in thermal comfort and thermal sensation were found in S1 and S2 for either periods in both groups.

## DISCUSSION

This experiment was undertaken to investigate the nature of the adaptation of the metabolic response to cold in humans. The results from the control indicate that two immersions separated by a week are sufficient to produce a reduction of about 10% in this response. The 27% reduction seen in the metabolic response of Group A in Period 1, but not in Period 2, suggests that the adaptation of the metabolic response is specific and confined to the deep body temperatures experienced during an habituation regime (table 1, figure 1). This finding leads us to reject *Hypothesis 1*. It is interesting, but speculative, to comment on the mechanism producing this alteration. Previous studies suggest that this is unlikely to be due to alterations occurring at the peripheral cold receptors (5, 8). A more likely candidate is a down-regulation in the response of thermoresponsive cells in the reticular formation (9, 10).

The data in figure 1 suggest that the habituation of the metabolic response is characterised by a delayed onset of shivering (threshold shift). However, when it is initiated the response has the same sensitivity for a given change in deep body temperature before and after habituation. This is confirmed in figure 2, in which the metabolic response of Group A is plotted against deep body temperature for Period 1, pre and post habituation. It should be noted from this figure that, although the metabolic response at a given deep body temperature is reduced following habituation (downward shift), the increase in  $\dot{V}O_2$  for a given reduction in deep body temperature remains the same. This finding leads us to accept *Hypothesis 2*.

It is concluded that the habituation of the metabolic response in man is specific to the body temperatures encountered during a habituation regime, and characterised by a reduction in the threshold but not the sensitivity of the response.

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